UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF AGRICULTURAL ECONOMICS

Operations Guidance Report on

WATER FACILITIES FOR BIG ELM, MULBERRY, NOODLE, BITTER, DEADMAN AND CEDAR CREEK WATERSHEDS TEXAS

Prepared by

WATER UTILIZATION SECTION
DIVISION OF LAND ECONOMICS

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Under the Provisions of the
Water Facilities Act
(Public Law No. 399, 75th Congress)

August 1939

ACKNOWLEDGMENTS

The base map of the area was compiled from Agricultural Conservation Program areal photography, from county geologic maps of the University of Texas Bureau of Economic Geology, and from county road maps prepared by the Texas State Highway Planning Department. Many data were supplied by local well drillers and farmers, and by the Water Department of the city of Abilene. The United States Geological Survey Topographic Sheets, the United States Geological Water Supply Papers, and the Reports of the Board of Water Engineers for the State of Texas were used in preparing the report. Population figures were taken from the 1939-1940 Texas Almanac. Chemical analyses of water were obtained from the Texas State Board of Health.

AUTHORIZATION

The report has been prepared in accordance with the provisions for operation of the Water Facilities Program authorized under the Water Facilities Act, Public Law No. 399, 75th Congress.

The area, consisting of the watersheds of Big Elm, Mulberry, Noodle, Bitter, and Deadman Creeks, was approved for area planning by Water Facilities Board on January 18, 1939. Operations were authorized to proceed as rapidly as mutually agreed upon by responsible field officials of the agencies concerned with the execution of the Program.

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WATER FACILITIES FOR BIG ELM, MULBERRY, NOODLE, BITTER, DEADMAN AND CEDAR CREEK WATERSHEDS TEXAS

SUMMARY

1. The average annual precipitation in the area is 24.66 inches.
2. The mean annual evaporation in the area is 61 inches.
3. The drainage areas total 1,185 square miles.
4. The average annual run-off rate for the area is 61 acre-feet per square mile.
5. The average annual yield of surface water for the area is 72,285 acre-feet.
6. Ground water is generally recoverable in sufficient quantities for stock and domestic needs in the areas indicated on Plate 1.
7. Throughout the remainder of the area, ground-water resources are uncertain as to distribution, quantity, and quality.
8. Retention of surface water for livestock and domestic needs is possible throughout the area because of favorable topography.
9. Nowhere in the area is recovery of ground water for irrigation purposes (other than garden plots) physically feasible.
10. Provisions for the irrigation of small gardens are to be made wherever possible.

11. Topographically irrigable land lies usually adjacent to streams and is subject to damage by floods. No recommendations are made for surface irrigation structures.

12. Present water facilities for domestic and livestock use in the area are inadequate both as to number and distribution.

I

PURPOSE AND SCOPE

The purpose of this report is to determine the available usable water supplies in the area and to make recommendations for a more beneficial use of these supplies to promote proper land utilization.

This report presents (1) a physical description of the area which may be considered as an inventory of agricultural resources in the area, (2) a brief review of the present use of the agricultural resources, and (3) recommendations for the future use of the area. The report is a preliminary presentation of data collected in the field and of data pertaining to the area which was obtained from various sources.

II

PHYSICAL DESCRIPTION OF THE AREA

Location of the Area

The area to which this report relates occurs in all or portions of Taylor, Jones, Shackelford, Callahan, and Nolan counties, Texas. It comprises the watersheds of Big Elm, Mulberry, Noodle, Bitter, Deadman, and Cedar Creeks and that area in Jones County which drains southward into the Clear Fork of the Brazos River.

The area extends from approximately longitude 99° 25' to approximately longitude 100° 15' west, and from about latitude 32° 12' to approximately latitude 32° 43' north and comprises 1,185 square miles or 758,400 acres.

Physiography

The area lies within the Osage Plains Section of the Central Lowland Province of the Interior Plains, and varies from gently rolling to rough broken hills. Large areas of gently rolling land are found near Abilene, Tye, Merkel, and Trent. The area around the headwaters of Big Elm, Cedar, and Mulberry Creeks is composed of rough breaks.

From the foothills of the Callahan divide to the Clear Fork of the Brazos the land slopes in a direction slightly east of north with a gradient of 17 feet per mile. The valley of Elm Creek, from the head to its emergence from the hills at Buffalo Gap, has an average gradient of 30 feet per mile in an easterly direction.

The area is topographically suited to the development of surface water storage structures for domestic and stock needs. Stream diversion and channel storage are not practicable in most of the area because of the extreme overflows during flood stage which result in consequent damage to works for storage or diversion.

In the lower portions of the several stream basins many areas adjacent to streambeds are topographically irrigable. However, practically all such land is subject to damage by floods because, in many cases, it is topographically lower than the banks of the stream channel.

The elevation of the area varies from 2,500 feet at the head of Elm Creek to 1,550 feet at the mouth of Elm Creek. Elevations of towns in the area are as follows: Abilene 1,738 feet; Buffalo Gap 1,926 feet; Merkel 1,872 feet; and Trent 1,914 feet.

The major streams within the area are Big Elm, Mulberry, Noodle, Bitter, Deadman, and Cedar Creeks. Minor streams include Long, Spring, Lytle, and Little Elm Creeks. The headwaters of the streams are characterized by narrow and sharply eroded rocky channels. Lower, where the streams traverse the rolling plains, the channels are

usually bordered on one or both sides by broad benches of compara-tively level land which, in many instances, lies slightly below the level of the stream banks. The average stream gradient of Elm Creek from the head to its emergence from the hills at Buffalo Gap is 20 feet per mile. From Buffalo Gap to the mouth of the stream, the average gradient is 8 feet per mile.

The area has relatively few trees. Small cedars (junipers) grow in the breaks of the Callahan Divide at the headwaters of Big Elm, Mulberry and Cedar Creeks. On the rolling land of the area and usually adjacent to the stream beds scattered growths of mesquite, postoak, live oak, western red oak, elm, hackberry, pecan, and red-bud are found. Grasses found in the area include mostly grama and mesquite grasses. The range areas contain shrubs such as catclaw, lotebush, agrite, sumac, and others. A Nolina species, locally called sacahuiste, is abundant.

Precipitation and Climate

Precipitation records of the United States Weather Bureau show an average annual precipitation of 24.66 inches at Abilene, Texas. The Abilene station is the only weather station within the area. Due to its central location within the area and because of the length of the records, the records of this station are more repre-sentative of the area than any other available information. The precipitation in the area is ordinarily sufficient for high crop

production. However, due to erratic occurrence of rainfall during the growing season, the practice of contouring cultivated land is found to increase production and to help toward eliminating crop failure. Planting dates are controlled to quite an extent by the irregularities in precipitation. The following data are from the records of the United States Weather Bureau regarding monthly and annual precipitation, maximum and minimum and extremes of high intensity of precipitation at Abilene.

Table 1.—MONTHLY AND ANNUAL AVERAGE PRECIPITATION
(55-year period)
ABILENE, TEXAS

Month	Inches
January	.90
February	1.03
March	1.29
April	2.61
May	4.14
June	2.62
July	1.96
August	2.10
September	2.78
October	2.57
November	1.33
December	1.33
Annual	24.66

Table 2.—MAXIMA AND MINIMA OF PRECIPITATION
ABILENE, TEXAS

Item	Amount (inches)	Month	Day	Year
Greatest precipitation in 72 hrs.	8.23	May	11-13	1928
Greatest Precipitation in 1 mo.	15.70	Aug.		1914
Maximum annual precipitation	46.43			1932
Minimum annual precipitation	10.85			1917

Table 3.—EXTREMES OF HIGH INTENSITY OF PRECIPITATION
DURING THE PERIOD 1886-1950, INCLUSIVE
ABILENE, TEXAS

Date	Rainfall in inches during 1 hour
May 22, 1908	2.70
October 22, 1908	2.27
July 31, 1911	3.46
August 3, 1928	2.03

The following table shows the average, monthly, seasonal, and annual temperatures compiled from the records of the United States Weather Bureau for Abilene, Texas. There are only slight variations from these figures in other parts of the area.

Table 4. MONTHLY, SEASONAL, AND ANNUAL AVERAGE TEMPERATURES
(53-year period)
ABILENE, TEXAS

Month		Average Temperature
December		46.0
January		44.7
February		47.7
	Winter — 46.1	
March		56.3
April		64.7
May		72.1
	Spring — 64.4	
June		79.8
July		83.0
August		82.7
	Summer — 81.8	
September		76.0
October		65.7
November		53.9
	Fall — 65.2	
	Annual — 64.4	

The absolute maximum temperature recorded for the 53-year period is 110.0 degrees; the absolute minimum is 6.0 degrees below zero. The highest monthly average temperature recorded during the same period is 87.2 degrees and the lowest monthly average 33.0 degrees.

On the basis of the 53-year record at Abilene, the average length of growing season is 232 days, the latest date of killing frost in the spring being April 23 and the earliest date of killing frost in the autumn being October 19.

A report by Wynkoop Kiersted, Consulting Engineer, Kansas City, Missouri, on Water Supply Conditions around Abilene, Texas, 1928, includes the following information on evaporation:

1. Direct determination of annual evaporation from water surface is possible only from the records of the Signal Service Station for the years 1887-88. Evaporation was calculated from data derived from readings of wet and dry bulb thermometers supplemented by and controlled by observations at several stations by means of the Piche evaporimeter.[1] This record gives an annual evaporation of 54.4 inches at Abilene, Texas.

2. Records of the Reclamation Service were used relating to evaporation at Lake Avalon, Agricultural College, Mesilla Park, Elephant Butte, and Roosevelt Dam. The average mean annual temperature of the five stations is 62.2 (1928) and that at Abilene 64.1 (1928). These records cover periods of five to nine years. The factors for reducing floating and landpan measurements to reservoir equivalents have been worked out and found to be 0.91 and 0.67, respectively. Using these factors of reduction, making corrections for difference

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1 Reference — Monthly Weather Review, September, 1888.

of elevation above sea level and reducing to Abilene conditions gave an annual evaporation of 59.9 inches.

3. Weather Bureau records at Spur, Texas, and at Austin, Texas:

The elevation at Spur is 2,300 feet, which is 300 feet above Lake Abilene. Records of the Weather Bureau at Austin, Texas, give open water evaporation as 0.75 of land values at Spur, which are land pan measurements. Using annual temperature at Spur and Abilene as 61.6 and 64.1 respectively and wind velocity as 5.43 miles per hour and 9.75 miles per hour, respectively, the mean annual evaporation from open water was computed to be 60.8 inches at Abilene.

Considering the above data, Mr. Kiersted used a mean annual evaporation figure of 61 inches, divided into monthly percentages as follows:

January	4.10	July	13.90
February	5.20	August	12.16
March	7.27	September	8.65
April	8.97	October	6.85
May	11.12	November	5.27
June	12.97	December	3.54

<u>Sunshine, Wind Movement, and Relative Humidity</u>

Table 5 gives the amount of sunshine, wind movement and relative humidity at Abilene, Texas, as recorded by the United States Weather Bureau.

Table 5.--SUNSHINE, WIND MOVEMENT, AND RELATIVE HUMIDITY
ABILENE, TEXAS

Item	Sunshine 8-yr. period Average Annual	Average Wind Velocity 45-yr.period Miles per hour[1]	Annual Average Relative Humidity Per Cent
Clear days	169		
Partly cloudy days	94		
Cloudy days	102		
Winter		10.0	
Spring		11.6	
Summer		9.2	
Fall		9.0	
Annual		10.0	
7:00 A.M.			75
12:39 P.M.			44
7:00 P.M.			48

Geology

The formations that make up the land surface in the Abilene area are largely of the Permian period. The several formations of this period are exposed successively from older to younger and from east to west across the area. Cretaceous strata form the land surface in portions of the area. Plate 2 shows the surface geology of the watershed.

1 Prevailing wind direction, south. Maximum velocity, April 8, 1892, 66.0 miles per hour.

Table 6.—GEOLOGIC FORMATIONS IN THE ABILENE AREA

Age	Group or Stage	Formation	Character	Thickness (Feet)
Quaternary	Recent		Dune Sands	
			—Unconformity—	
Cretaceous	Fredericksburg (Undifferentiated on geologic map)	Edwards	Massive Caprina Limestone, chert layers	20-75
		Comanche Peak	Chalky & Sandy Limestone	60-80
		Walnut Clay	Yellowish, Sandy clay and marl	4-10
	Trinity	Undifferentiated	Basal Sands	30-150
			—Uncomformity—	
Permian	Double Mountain	Blaine	Gypsum beds, shales, thin dolomites, Dog Creek shale	50-250
			—Uncomformity—	
		San Angelo	Conglomerates, sandstones, clay	80-170
			—Uncomformity—	
	Clear Fork (Undifferentiated on geologic map	Choza	Red shales, thin dolomites, Merkel dolomite persistent	625+
		Vale	Bullwagon dolomite included in this formation. Red gypsiferous, sandy shales	[illegible]
		Arroyo	Shales, limestones & gypsum	260+
	Wichita	Leuders	Limestones and shales	50+

The oldest beds outcropping in the area are the limestones and clays known as the Wichita group of the Permian system, which cover a small portion of the watershed on the northeastern edge.

The Clear Fork group of the Permian system, and next in age, covers approximately 80 per cent of the surface of the watershed.

Above the Clear Fork group to the west the San Angelo sandstones and shales of the Double Mountain group outcrop in a strip a few miles in width, and extend in a north and south direction.

The Blaine gypsum beds of the Double Mountain group form the surface geology of a small area on the western edge of the watershed. Along the southwestern, southern, and eastern edges of the drainage basins, the Fredericksburg and Trinity groups of the Cretaceous period lie on the surface; these remnants form a portion of the Callahan Divide.

The geological formations affecting water supply are described below.

The beds exposed over the greater part of the watershed belong to the Permian system. In general, formations of Permian age yield only small quantities of water which is usually a poor quality. It therefore appears reasonable that over the greater part of the Permian outcrop in this area, with some exceptions, ground-water development is highly unsatisfactory from the standpoint of quantity and quality. The following is a brief description of the Permian groups and formations in ascending order and their hydrologic characteristics.

The Leuders formation, a member of the Wichita group, consists of limestones and shales. It outcrops extensively in stream channels in the highly dissected eastern part of the watershed. Westward, it dips beneath younger formations, and near Merkel it is many hundred feet below the surface. This formation yields water of a poor quality in extremely small quantities, and is therefore not to be considered in ground-water development.

Overlying the Leuders formation are three closely related formations known as the Arroyo, Vale, and Choza, in ascending order. These formations are very similar in lithologic characteristics, consisting in general of interbedded shales, sandy shales, dolomites, limestones, and gypsum. In view of the close similarity between these beds, they have not been clearly differentiated, and will therefore be discussed collectively as the Clear Fork group, and is so indicated on the accompanying Plate 2. The Clear Fork group are exposed at the surface over approximately 80 per cent of the watershed. These rocks dip to the west, and their combined thickness averages about 1,000 feet.

With some exceptions, ground-water development in the Clear Fork group is highly unsatisfactory as to both quantity and quality. Field investigation of wells producing from various members of the group furnished conclusive evidence that, in general, the Clear Fork beds are poor sources of water. The investigation disclosed

that Clear Fork wells produced very limited supplies of water which are highly contaminated with calcium sulphate.

In the vicinity of Merkel and extending north through the area in a broadening band, as indicated on Plate 1, the Clear Fork is a rather reliable aquifer. It is reasonably certain that over this area, the Choza member of the Clear Fork group is the surface formation, and the principal aquifer. The Choza is composed chiefly of red shales with some thin interbedded dolomites. The shales are jointed and broken and yield water in quantities sufficient for stock and domestic purposes as well as for garden irrigation. Locally, in this general area, the Choza contains gravel lenses which yield moderate supplies of ground water. Throughout the Merkel area, and north through the watershed, the Choza may be regarded as a fairly reliable aquifer, yielding water in moderate quantities.

Overlying the Clear Fork group in ascending order are the San Angelo and Blaine formations, members of the Double Mountain group.

The San Angelo formation averages about 80 feet in thickness, and consists of conglomerates, sandstones, and clays. It outcrops in small areas in the extreme western part of the watershed. This formation, in other parts of Texas, is usually a reliable aquifer; however, in this watershed, it apparently yields moderate supplies only in local areas. The quality of San Angelo water is comparable to that in the Choza. In local areas, as indicated on Plate 1, the

San Angelo yields water in quantities sufficient for stock, domestic, and garden irrigation purposes.

Overlying the San Angelo is the Blaine formation. This formation is impregnated with vast quantities of gypsum, and yields only small quantities of highly mineralized water. It is a poor aquifer in all respects, and should not be considered in ground-water development in this area.

The Cretaceous system in this area is represented by the following groups and formations:

Group	Formation	Character	Thickness (feet)
Fredericksburg	Edwards	Limestones, some chert	20-75
	Comanche Peak	Sandy & chalky limestones	60-80
	Walnut Clay	Yellowish, sandy clay & marl	4-10
Trinity	Undifferentiated	Basal Sands	30-150

The Cretaceous formations outcrop in normal sequence over the southern part of the area, as shown on Plate 2. In the extreme southeastern part of the area the Fredericksburg has been removed by erosion, exposing the Trinity.

The basal sands (Trinity) constitute the only water-bearing formation of any importance in the Cretaceous rocks throughout this watershed. These sands range in thickness from 30 to 150 feet and are comprised of rather coarse-grained, clear to brownish quartz grains. In general, the sands are poorly cemented and freely yield water in quantities sufficient for stock and domestic purposes.

The quality of water produced from this formation is good.

The area is located near the eastern rim of the Permian basin. The beds dip slightly to the west. The Cretaceous beds covering a portion of the area have a gentle dip to the southeast. Structural geology has little or no effect upon the ground water supply of the area.

Ground Water

Potable ground water is generally recoverable in adequate quantities for stock and domestic needs in the areas indicated on Plate 1. The aquifers along the Callahan Divide are the limestones of the Fredericksburg formation and the sands and gravels of the Trinity formation. In these portions of the area, some wells are found which exceed 200 feet in depth but most wells reach the aquifers at lesser depths. Some ground water occurs locally in alluvial wash along the larger streams.

In the western portion of the area potable ground water is recoverable from sand and gravel lentils and from jointed clays of the San Angelo formation. Locally, throughout the entire area, ground water is recoverable in small quantities from jointed clays of other Permian formations. Areas where Permian clays are sufficiently jointed to store and yield adequate quantities of ground water for stock and domestic use are difficult to locate by other than exploratory drilling methods. Well depths in the Permian formations

vary from 10 feet to 100 feet and yields are seldom more than sufficient for stock and domestic demands.

Very little ground water is recovered in the area for industrial purposes.

The quantity of ground water recovered for irrigation is limited to that used for gardens in rural areas and small towns.

Ground water in the area originates from precipitation falling locally within the area. The quantity available varies with rainfall as evidenced by failure or lowering of water level in many wells during drought periods. There is little if any recharge from outside areas.

Underground movement of water is limited to comparatively small local areas, as evidenced by large areas in which little or no ground water occurs. The Fredericksburg and Trinity formations generally yield water readily in adequate quantities for stock and domestic purposes. The Permian formations, except in the very local instances of jointed clays, yield only meager quantities of ground water.

The quantity of ground water discharged through springs and spring-fed streams in the area is very small. A few small springs occur near the base of the hills of the Callahan Divide.

Ground water occurring in the Trinity and Fredericksburg formations is usually of good quality. Throughout the remainder of the area the quality of ground water, where available, is very poor due to its occurrence in and passage through the Permian formations.

Ground water occurring in the Permian formations is known locally as "gyp water" because of its comparatively high content of gypsum (calcium sulphate). The chemical analysis of water from the town well at Clyde, located in the Trinity sand formation bordering the east edge of the area, shows a total alkalinity of 385 parts per million and a total hardness of 498 parts per million. No chemical analyses of ground water in the Permian formations of the area are available.

Surface Discharge

Precipitation in this area is erratic in occurrence and intensity. Storms of high intensity are often reflected in damaging flood flows. Periodic and damaging droughts are not uncommon.

In the analysis of stream discharges at two gaging stations on the Clear Fork of the Brazos, one of which is located in the area, correlations between discharges and annual precipitation are shown.

While there are no stream measurement records available for any of the streams with which this report is concerned, a gaging station at Nugent in Jones County on the Clear Fork of the Brazos River measures stream flows which include discharges from the several streams of the area. Another gaging station is also maintained at Fort Griffin, Shackelford County, on the Clear Fork of the Brazos River. Records of stream discharge at both stations are shown by tables, the latter as a comparison of the discharge and discharge rates with the Nugent station.

Table 7 gives the discharge records at Nugent, Jones County, and Table 8 shows discharge records at Fort Griffin, Shackelford County. The 13.7-year record at Nugent shows an average annual discharge of 125,700 acre-feet from a drainage area of 2,220 square miles. The maximum recorded discharge occurred in 1932 at the rate of 47,000 cubic feet per second.

The Fort Griffin discharge records have been kept over a period of 13.8 years. The average annual discharge is 205,000 acre-feet from a drainage area of 5,970 square miles. The maximum measured discharge of 33,600 cubic feet per second occurred in 1932.

Table 7.—STREAMFLOW RECORDS AT NUGENT, JONES COUNTY, ON THE CLEAR FORK OF THE BRAZOS RIVER[1]

Year	Annual Discharge (Acre-feet)	Maximum (Cubic Feet per Second)	Discharge Date
1924	54,700	5,100	May 28
1925	67,300	5,800	May 10
1926	85,400	9,620	June 19
1927	79,000	7,520	April 14
1928	211,000	11,500	May 20
1929	82,800	5,420	September 11
1930	100,000	5,980	May 13
1931	73,900	6,220	December 6
1932	518,000 (Max.)	47,000	September 8
1933	84,800	4,100	May 15
1934	23,400 (Min.)	1,330	November 21
1935	256,400	16,100	June 2
1936	105,800	17,600	September 28

1 United States Geological Survey Water Supply Papers. Records available for period February 1924 to September 1936. The drainage area covers 2,220 square miles. The average annual discharge at Nugent is 125,700 acre-feet. The maximum measured discharge was 47,000 cubic feet per second on September 8, 1932. No flow was recorded during some periods.

Remarks: Records good. Small municipal diversion above station. Unrecorded returns to stream.

Average annual run-off per square mile — 57 acre-feet.
Weighted mean annual precipitation of drainage area — 23.1 inches.
Run-off factor — 4.6 per cent of precipitation.

Table 8.—STREAMFLOW RECORDS AT FORT GRIFFIN, SHACKELFORD COUNTY, ON THE CLEAR FORK OF THE BRAZOS RIVER[1]

Year	Annual Discharge (Acre-feet)	Maximum (Cubic Feet per Second)	Discharge Date
1924	114,000	5,800	May 26
1925	138,000	6,820	May 11
1926	187,000	12,500	June 21
1927	105,000	5,040	April 15
1928	283,000	12,100	May 21
1929	149,000	5,710	September 13
1930	235,000	Not determined	June 15
1931	127,000	Not determined	December 7
1932	711,000 (Max.)	33,600	September 10
1933	159,000	7,140	May 26
1934	35,500 (Min.)	3,410	October 15
1935	421,000	18,600	May 20
1936	165,500	14,400	September 29

1 United States Geological Survey Water Supply Papers. Records available for 13.8-year period. The drainage area covers 3,970 square miles. The average annual discharge at Fort Griffin is 205,000 acre-feet. The maximum measured discharge was 33,600 cubic feet per second occurring on September 10, 1932. No flow was recorded during some periods.

Remarks: Records excellent. Small diversions above station for municipal and irrigation uses.

Run-off per square mile — 52 acre-feet.
Weighted mean annual precipitation of drainage area — 23.7 inches.
Run-off factor — 4.1 per cent of precipitation.

Since the characteristics of the watersheds drained by the Clear Fork of the Brazos River gaged at Nugent, Jones County, and at Fort Griffin, Shackelford County are similar to the Noodle, Bitter, Mulberry, Elm, and Deadman Creek watersheds, these data are used as a basis for estimating discharge from the streams embraced in this report. Watershed slopes, stream gradients, geology, soils, vegetation, storm frequency, and precipitation are similar throughout the compared basins.

Mean annual precipitation estimates for the areas included above the two gaging stations and for the area discussed in this report are based on isohyetals of annual precipitation.

With a mean annual precipitation of 23.1 inches estimated for the watershed of the Clear Fork of the Brazos River above the gaging station at Nugent in Jones County, Table 7 shows an average discharge rate of 57 acre-feet per square mile for the 2,220 square mile area. This quantity of discharge, compared to the estimated mean annual precipitation of 23.1 inches for the watershed, gives an average percentage run-off of 4.6 per cent. Small municipal diversions above the gaging stations take some water, but return flows partially offset the diversion.

At Abilene, Texas, the 53-year precipitation record averages 24.66 inches annually and is considered applicable to the basins concerned. Hence the precipitation record at Abilene is used for

purposes of estimating discharge quantities. On this basis the annual unit run-off is estimated at 61 acre-feet per square mile for the basins considered.

Considering the discharge records of the area above the gaging station at Fort Griffin in Shackelford County on the Clear Fork of the Brazos River with a total area of 3,970 square miles, and a mean annual precipitation of 23.7 inches for the drainage area, the average annual discharge per square mile is 52 acre-feet. This is equivalent to a run-off factor of 4.1 per cent of the annual precipitation. Table 8 is a summary of the discharge record at Fort Griffin.

Since, however, the physical characteristics of the drainage basin above Nugent is comparable in more respects to the areas concerned, it appears logical to use the corrected Nugent record as a basis for estimating the yields of the other basins. Therefore, as shown above, the annual yield per square mile of drainage area is estimated to be approximately 61 acre-feet or 4.6 per cent of mean annual precipitation.

The drainage area in the watershed under consideration totals 1,185 square miles. Using the estimated run-off rate, 61 acre-feet per square mile, the average annual yield of surface water for the drainage basin is 72,285 acre-feet.

The following tabulation shows the various creeks within the area, their drainage areas, and the probable average annual yields from these streams, using the run-off rate of 61 acre-feet per square mile.

Creek	Drainage Area (Square Miles)		Estimated Average Annual Yield (Acre-feet)	
Deadman		192		11,712
Big Elm				
Little Elm	64		3,904	
Buck Creek	19		1,159	
Rainey	42		2,562	
Lytle	67		4,087	
Cedar	55		3,355	
Big Elm	229	476[1]	13,969	29,036
Mulberry		228		13,908
Bitter Creek		103		6,283
Noodle Creek		60		3,660
Clear Fork of Brazos River		126		7,686
TOTAL		1,185		72,285

Soils

The soils and their general agricultural use of the Big Elm, Mulberry, Noodle, Bitter, Deadman, and Cedar Creek Watersheds are described very completely in Bulletin No. 431, "The Soils of Texas," published by the Texas Agricultural Experiment Station. The most

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1 Total drainage area by Big Elm and tributaries.

common soil series found in this area are: Valera—Rough stony land group; Abilene—Roscoe—Foard group; Miles—Vernon group; and Frio—Spur—Leona group.

The Valera-Rough stony land group covers approximately 65 per cent of this area.

The series is characterized by brown or dark brown surface soils, locally nearly black. The surface is moderately rolling to very rolling and some slopes are steep. The steep slopes in many places are eroded. The native vegetation is largely short grasses, mesquite, buffalo, and various bunch grasses. However, in places, especially on the stony clay, there are many small trees, largely small cedar (Juniper), shin oak, live oak and western red oak, red-bud, and many shrubs, including cat's claw, lote bush, agrite, sumac, and others. The deeper soils, clay and clay loam, which are inter-mixed with the large areas of stony clay, are fairly productive when moisture conditions are favorable and they are well suited to the general farm crops. A small amount of the deeper soils is farmed and produces cotton, corn, small grains, sorghums, and some other crops. Most of these soils are in cattle, sheep, and goat ranches.

The Abilene-Roscoe-Foard group covers approximately 28 per cent of the area and the series included within this group may be described as follows:

The topsoils of the Abilene soils are brown or dark chocolate-brown in color. The soils are granular and the subsoils, though quite heavy, are of fairly open and permeable character. A moderately large amount of organic matter is present. For the most part the soils are deep. The surface is undulating to nearly flat, though on some slopes the soils have been thinned by erosion. The natural vegetation is mainly short grasses, buffalo grass (locally called mesquite grass) with some other grasses such as grama, needle, and on the sandy soils, some coarse bunch grasses. A scattering growth of small mesquite trees occurs with some lote bush and a few of the other shrubs. The soils and subsoils readily absorb water and the deep, heavy clay subsoils and substrata act as a reservoir to hold a large amount of water for growing crops. These soils are among the most highly esteemed soils of the region for farming and are extensively utilized for the general farm crops. These consist of cotton, corn, sorghums, small grains, and other crops, to all of which the soils are well suited.

The Roscoe soils have black or very dark brown surface soils. The chief soils of the series are of clay and clay loam textures. The soils are moderately granular but the subsoils are rather heavy and slowly penetrated by water. The soils occupy very flat and some slightly depressed areas having very slow natural drainage. The natural vegetation is chiefly short grasses with scattered mesquite trees. The soils are limited in extent and are usually associated

with the Abilene soils. They are well suited to cotton, corn, grain sorghums, and other general farm crops, and as the soils are nearly flat they collect and retain a very large proportion of the rain water and are fairly drought-resistant, provided a supply of moisture is beneath the soil before dry seasons begin. The soils are also well suited to small grains.

The Foard soils have light brown to dark brown surface soils. A characteristic feature is the presence in many places of small bare spots with a light-colored, smooth surface practically devoid of vegetation. These are locally called "alkali spots" and the soil material contains a considerable percentage of sodium chloride and less amounts of other salts. There is a tendency for the soils to dry out to a very hard mass. The subsoils are extremely tough and dense. Water penetrates them slowly. The Foard soils do not contain a large amount of organic matter. The surface is generally quite flat, and though there is a relatively light run-off of rain water, soils are often too tight to allow easy penetration. Therefore, the soils are not highly drought-resistant. A considerable amount of the land is in cultivation and fairly good yields are secured when moisture conditions are favorable. The principal crops grown are cotton, sorghums, and small grains, to all of which the soils seem well suited. The principal types are a very fine sandy loam, clay loam and clay. Where uncultivated they support a heavy growth of short grasses which provide valuable forage for

grazing. Small mesquite trees also grow rather abundantly.

The Miles-Vernon group covers approximately 5 per cent of the area and may be described as follows:

The topsoils of the Miles soils are reddish-brown, brownish-red or brown. The Miles topsoils are granular while the subsoils are of open structure and are readily penetrated by air and water. These soils are developed on smooth to fairly rolling surfaces with some rather steep slopes. The soils have a natural rapid surface and subsurface drainage. Much of the surface is sufficiently sloping to allow rapid run-off of rain water, which is lost to crops, while erosion injures the soils by removing valuable soil materials and plant food constituents. Where smooth or of sandy texture, the soils absorb much of the rain water, which is retained in the subsoils. In very dry seasons crops suffer least on the sandy soils which are underlaid by clay subsoils. The fine sandy loams and other sandy soils are the most extensive of the series. The natural vegetation on the sandy soils is mainly bunch grasses with some shin oaks growing thickly in places. On the heavy soils the short grasses, grama grasses, and others grow. A scattered growth of small mesquite trees and various shrubs occurs on the heavier soils. The Miles soils occupy many large areas, but in places are intimately associated with small areas of the Vernon soils. They mostly cover the smoother divides, and the associated Vernon soils

cover the more sloping and rolling areas. The fine sandy loams are considered quite desirable for all of the general crops on account of their drought-resistant qualities. They are suited to cotton, grain sorghums, fruits, and vegetables. The heavier soils, where sloping, do not collect much rain water and, therefore, do not strongly resist droughty conditions. The deeper heavy soils are quite productive, being suited to cotton, grain sorghums, and small grains. The soils are farmed quite extensively; considerable areas of the virgin soils comprise valuable ranch lands.

The Vernon soils have red, reddish-brown, or brownish-red calcareous surface soils. The soils and subsoils are mostly of open, granular structure and of ready penetrability. Owing to the imperfect development of the Vernon soils due to excessive erosion, the soil layers are thin in many places and the parent formations of calcareous clay or sandy clay lie near the surface and in places are exposed. The beds of parent materials, Red Beds, have in places some strata of gypsum, limestone, and sandstone, and on some greatly eroded surfaces these materials are exposed. In the rough lands such areas are known as "gyp hills." The surface of these soils ranges from smoothly undulating to very rolling, with fairly steep slopes. The soils and parent-materials are very susceptible to erosion and in many places, even under natural conditions, where a heavy grass cover occurs, the surface is so cut and denuded of soil or dissected by so many gullies that the land has little or no

value for cultivated crops. The soils range in texture from fine sandy loam to clay. Probably the very fine sandy loam is the most extensive. The natural vegetation is mainly grasses. These grow thickly on the deeper soils accompanied by a scattering of mesquite trees and various shrubs. The short grasses with some grama and other grass are abundant on the heavy soils, but coarse bunch grasses, grama grasses, and other predominate on the sandy soils. The Vernon soils are quite extensive and occupy exclusively some large areas. The more deeply developed soils are quite productive and are suited to many kinds of crops, but in many places the thin eroded soils are not highly productive and many slopes are so steep that a great deal of the rain water runs off and is lost for use of vegetative growth. The smoother soils are used to a considerable extent for cotton, corn, grain sorghums, and on the heavier soils for some small grains. The natural vegetation of these soils provides good grazing, and large bodies of virgin soils occur on many of the cattle ranches of the region.

The Frio-Spur-Leona group covers approximately 2 per cent of the area and the series included may be described as follows:

The Frio soils are light brown, calcareous soils which dry out to a pronounced grayish cast. These are deep soils and the subsoils, though mostly heavier, are crumbly and have the same granular, open structure as the surface soils. On account of flat surface, natural drainage is slow although the lighter-textured soils,

generally lying near the streams and in places underlain by beds of gravel, are slightly higher and have fairly rapid surface drainage and free under-drainage. Tree growth consists of mesquite, oak, and other trees, and some pecan trees grow in the well-drained positions. These soils are very productive and the subsoils afford a good reservoir for soils moisture, which gives them a good drought resistance. They are highly productive and suited to many crops. They are farmed to a considerable extent, cotton, sorghums, and various other feed crops comprising the chief crops grown.

The Spur soils are light brown to dark chocolate-brown in color. Several types, ranging in texture from sandy to clay loam, occur in this series. The soils occupy bottomland and are overflowed occasionally. They are deep, well-drained soils, friable and permeable, and are quite productive though the very light sandy types are not highly so. These soils hold large amounts of water and have very favorable moisture conditions for crop growth. They are suited to many crops and a large part is farmed. The principal crops are cotton, corn, sorghums, alfalfa and various other crops.

The Leona soils have dark brown or black calcareous top soils. These are deep, granular soils, containing considerable organic matter, and are underlain in places by beds of rounded gravel. The surface is flat and drainage is readily effected through the soil and subsoil material. Overflows are infrequent. Various trees

grow on the soils and pecan trees grow where underdrainage is most rapid. The soils are productive and suited to the general farm crops. Some areas of the soils are successfully farmed.

III

PRESENT USE OF AREA

Water Use

Water for stock and domestic use in the area is obtained from three sources: ground water in certain portions of the area, surface water discharge, and rain water retained in cisterns from roof catchments.

In portions of the watershed wells furnish sufficient water for domestic and stock purposes, while in other portions ground water is of poor quality or insufficient in quantity for both domestic and stock use. In many instances individuals augment their domestic and stock water supply by the use of stock ponds for surface water storage.

The area lies principally within Permian strata where scarcity of potable ground water is characteristic. Many surface water retention structures have been built through private initiative, county assistance, and the Agricultural Conservation Program. However, existing works are not adequate to supply water for domestic and stock needs.

The following municipalities within the area in Taylor County, Texas, have public water works: Abilene, Merkel, and Trent.

The City of Abilene has storage reservoirs which retain surface flow from creeks within the watershed. The following table illustrates the lakes, their source of supply, capacity, drainage areas, and present usage.

Table 9.—LAKES IN THE AREA

Lake	Stream	Capacity (Acre-feet)	Drainage Area (Sq.mi.)	Year Completed	Present Consumption (Million Gallons Per Day)
Lake Abilene	Big Elm Cr.	10,000	110	1922	
Lake Kirby	Cedar Creek	9,200	44	1928	2.209[1]
Lytle Lake	Lytle Creek	1,380			
Fort Phantom	Big Elm Cr.	73,700	480	1938	

The underflow in the alluvium of Big Elm Creek near Lake Abilene is an additional source of water. The amount of water available from this source is controversial. Abilene has developed its water supply for considerable expansion in the future both industrially and for future increase in population.

Merkel, Texas, in Taylor County, with a population of 2,200, uses ground water recovered from 6 wells, no one of which will yield over 80 gallons per minute. There are approximately 200 private wells used within the village. Water in Merkel is only partially

1 Based on 10-year average, 1928-1937.

metered, but the city clerk estimates that the 160 connected users average a monthly use of 640,000 gallons of water. Due to the hardness of the ground water at Merkel, the Santa Fe railroad discontinued its water station there and now obtains water at Abilene, Texas, where the water is treated for hardness by the city.

The town of Trent, Texas, in Taylor County, with a population of 412 recovers ground water for its municipal water supply. The total consumption of flat rate users is not metered and some private wells are also used. Consequently the total withdrawal for municipal use is unknown.

Irrigation from surface water sources involves only a small portion of the watershed. Surface irrigation is limited because topography precludes economically feasible construction of storage or diversion works. Furthermore, much of the physically irrigable land is subject to overflow during flood stage.

There are no active irrigation districts in the area. The Brazos River Conservation and Reclamation District is active in the Brazos River Watershed. However, proposed development of domestic water supplies does not interfere with the program of the Brazos River Authority.

Table 10 shows a list of the appropriations of public waters from streams in the watershed discussed in this report. This table shows the purpose of the appropriation, in some cases the rate of

Table 10.--APPROPRIATION OF PUBLIC WATERS
FROM SEPTEMBER 1, 1913 to 1936

Date Filed	Applicant	Stream	County	Purpose	Rate of Diversion (Cu.Ft. per Sec.)	Means of Diversion	Date of Action on Application	Area to be Irrigated (Acres)	Quantity Granted (Acre-feet per annum)
Apr.22, 1914	J. M. Thomas et al	Clear Fork	Jones	Irrigation	80	Gravity	June 8, 1914	10,200	
May 11, 1914	Wm. Fulwilder	Big Elm	Taylor	Irrigation	30	Pumping	June 13, 1914	116	232
May 11, 1914	W. J. Young	Big Elm	Taylor	Irrigation	30	Gravity	June 13, 1914	177	354
May 11, 1914	M. P. Roberts	Big Elm	Taylor	Irrigation	30	Pumping	June 13, 1914	80	160
May 11, 1914	J. M. Radford	Cedar	Taylor	Irrigation	0.5	"	"	20	40
May 12, 1914	E. M. Hawk	Clear Fork	Jones	"	3	"	June 27, 1914	85	170
July 3, 1914	S. L. Hedges	Clear Fork	Jones	"	8	"	Aug. 8, 1914	300	600
July 3, 1914	Mrs. Martha Ruark	Clear Fork	Jones	"	4	"	"	80	160
July 3, 1914	B. Parsley	Clear Fork	Jones	"	4	"	"	100	200
July 3, 1914	M. L. Addington	Clear Fork	Jones	"	4	"	"	100	200
July 3, 1914	A. J. Addington	Clear Fork	Jones	"	2	"	"	75	150
July 3, 1914	A. G. Britton	Clear Fork	Jones	"	10	"	"	190	380
Sept. 18, 1914	J. B. Pruitt	Cedar	Taylor	"	4	"	Dec. 2, 1914	50	103
Oct. 13, 1914	H. K. Herman	Cedar	Taylor	"	2	"	"	12	24
Oct. 27, 1914	T. G. Moore	Clear Fork	Jones	"	3	"	Feb.15, 1915	40	80
June 23, 1918	City of Abilene	Big Elm	Taylor	Municipal	-	Dam & Grav.	Mar. 15, 1918		1665
Sept. 3, 1918	J. L. Ohlavsen	Big Elm	Taylor	Irrigation		Reservoir	Oct. 14, 1918	494	100
Feb. 18, 1919	M. H. R. Cross	Big Elm	Taylor	"	10	Pumping	Mar. 3, 1919	58	116
May 2, 1921	Abilene Gas & El.Co.	Cedar	Taylor	Mining		Dam	July 2, 1921		10
Apr. 4, 1922	J. D. Williams	Cedar	Taylor	Irrigation		Dam	June 5, 1922		100
Jan. 1, 1923	Wm. B. Oliver	Big Elm	Taylor	Irrigation		Dam	Mar.26, 1925		20
July 26, 1926	R. G. Young et al	Clear Fork	Jones	Irrigation		Pump	Sept.27, 1926	42	84
July 26, 1926	J. H. Chorn	Clear Fork	Jones	Irrigation		Pump	Sept.27, 1926	33	66
Aug.16, 1926	C. C. Blair	Clear Fork	Jones	Irrigation		Pump	Sept.27, 1926	14.5	29
Mar. 3, 1927	Humble Pipeline Co.	Clear Fork	Jones	Mining		Pump	Apr. 25, 1927		28
July 8, 1927	R. B. Easton	Clear Fork	Jones	Irrigation		Pump	Aug.29, 1927	30	60
Oct. 10, 1927	City of Abilene	Cedar	Taylor	Mining, etc.		Dam	Nov. 28, 1927		242
Feb. 29, 1928	H. B. Finch	Clear Fork	Jones	Irrigation		Pump	Apr.30, 1928	8	16
Oct. 12, 1928	West Tex. Utility Co.	Lytle	Taylor	Industrial		Dam	May 26, 1928		6,500
Mar. 25, 1937	City of Abilene	Big Elm	Taylor Jones	Municipal		Dam	June 17, 1937		20,690

diversion, means of diversion, acres to be irrigated and quantity of water granted by the State Board of Water Resources. For the most part, other than municipalities, the appropriated water is not being fully used because of physical limitations previously pointed out.

Ground water is not recoverable in sufficient quantities for irrigation purposes. The city of Abilene has constructed a gallery in the alluvium fill above Buffalo Gap on Big Elm where the under-flow may be recovered at rapid rates. Windmills are in use in portions of the area, and where there is a surplus of water above the needs for domestic and stock consumption irrigation of gardens and lawns is done.

Industries have for the most part depended on municipal water works to supply them with water because ground-water supplies are limited throughout the watershed. Another factor limiting the use of ground water is the hardness of the supply in portions of the area. By using municipal water the various industries receive water that has been treated.

Land Use and Types of Farming

There are approximately 375,000 acres of the area in native pasture. The range is spotted and evidences of over-grazing rather pronounced. In some pastures the damage has been slight while in

others some native grasses have been almost annihilated. Broom wood, which is non-palatable, is on the increase.

In Taylor County the County Agent estimates that an average of 16 acres is required to carry an animal unit. In the best pastures the carrying capacity is somewhat greater, 10 to 12 acres being required per animal unit. It is estimated that acreage necessary to carry an animal unit has increased considerably.

Approximately 50 per cent of the area is in cultivation. Certain sections of the area are practically all in pasture, while others are nearly all under cultivation. The northern part of Taylor and the southern part of Jones counties have a high percentage of land in cultivation.

Cotton, oats, grain sorghums, wheat, corn, and sudan are the principal crops. About 40 per cent of the cultivated land is in cotton, 22 per cent grain sorghums, 18 per cent oats, and 8 per cent wheat. These proportions vary from year to year, depending upon moisture and other seasonal influences.

From 1929 to 1934, inclusive, average yields per acre were as follows: corn 12 bushels, cotton 128 pounds, grain sorghums 11.7 bushels, oats 23.5 bushels, and wheat 10 bushels.

Since little attention had been given to erosion by water, considerable erosion has taken place both in the cultivated and pasture areas of higher land slopes. Few erosion gullies are found,

but sheet erosion in some areas has been severe. Some wind erosion has occurred in the sandy areas of Jones County.

Erosion has been the big factor in reducing the soil fertility. Most of the area is still fertile enough to produce good crops when ample moisture is available but present droughts appear to have a more widespread effect than those of the past. Most of the land has been in cultivation long enough to have most of the organic matter "burned out" and consequently it does not have sufficient moisture holding capacity. However, little land has been abandoned.

The sections which have a high percentage of land in cultivation are cash crop areas producing cotton as a primary crop. The farms in these areas are small and have little or no pasture. The cash crop farms seldom exceed 160 acres in size. More than 50 per cent of the farms are operated by tenants.

General farming is rather well distributed throughout the area. This type of farming is carried on in the shallow soil areas where the topography is rather rolling to rough with fairly frequent level valleys of good land. Feed crops are produced to supplement the livestock enterprise which is the main source of income. A small percentage of the cultivated acreage is used to produce cotton. The size of these general farms range from 240 to several thousand acres.

Land Values and Public Facilities and Population

According to the 1935 Census the average value of land in the area is approximately $25.00 per acre. The value of cultivated acreage will probably range from $25.00 to $40.00 per acre. The grazing land is valued from $5.00 to $15.00 per acre. Land that takes 16 acres for each animal unit is not worth more than $6.00 per acre.

Institutional facilities are quite satisfactory. Some school districts were originally too small. Most of these have been consolidated to make districts large enough for adequate support of the educational needs. The area is unusually well supplied with hard-surfaced roads. Most of the land owners have telephones and the Rural Electrification Administration has recently built power lines in various sections of the area.

The total population in this area decreased slightly from 1910 to 1920. There was a substantial increase, however, from 1920 to 1930. The farm population decreased in several precincts between 1930 and 1935. It is believed that the more intensely cultivated areas have a larger population than they can permanently support. The principal city in the area is Abilene with a population of 29,000. Merkel and Trent are small towns in the area with populations of 2,200 and 412 respectively.

IV

RECOMMENDED AREA UTILIZATION

Reviewing the physical inventory of the water resources of the area and the present use of these resources, there remains a balance of both surface water and ground water that may well be developed to fulfil the stock and domestic needs of the area.

Surface retention structures are recommended where ground water is not available or is insufficient to supply domestic and stock needs. These will usually be comparatively small earth fills with suitable spillway facilities.

In some portions of the area where ground water is available more wells and windmills may be constructed. It is advisable in portions of the area to make borings or test holes for the location of ground-water supplies. The ground water in the Permian strata is usually recovered from shallow depths and drilling tests will consequently be inexpensive. Where ground water has been located wells may be developed and windmills installed for the recovery of water.

Many existing wells and windmills require repairs and some stock tanks are in need of repair and rebuilding. This may be considered as an essential part of the Water Facilities Program in the area.

Irrigation is not contemplated in this area except on small areas for home gardens. Experience of Farm Security Administration officials in this area has indicated that irrigated gardens have helped considerably in enabling some families to attain a higher standard of living. This practice should be encouraged wherever adequate surface or ground-water supplies are available. When equipping domestic and livestock wells or repairing such wells, special attention should be given to providing storage facilities sufficient for the irrigation of a family-sized garden.

Irrigation in the area is desirable but physical factors preclude justifiable irrigation projects. Stream diversion is possible in certain portions of the area. However, since the physically irrigable areas are usually adjacent to such streams and are subject to overflow several times a year, development of such facilities is not recommended.

The necessity for making adjustments in land use and types of farming has not been considered in this report. However, yields of cash crops are not high in the area under the present dry land farming practices and the area is adapted to livestock production. The water facilities recommended are for domestic, livestock, and family garden irrigation purposes; and it is not contemplated, therefore, that they will be installed where by doing so the production of cash crops will be encouraged.

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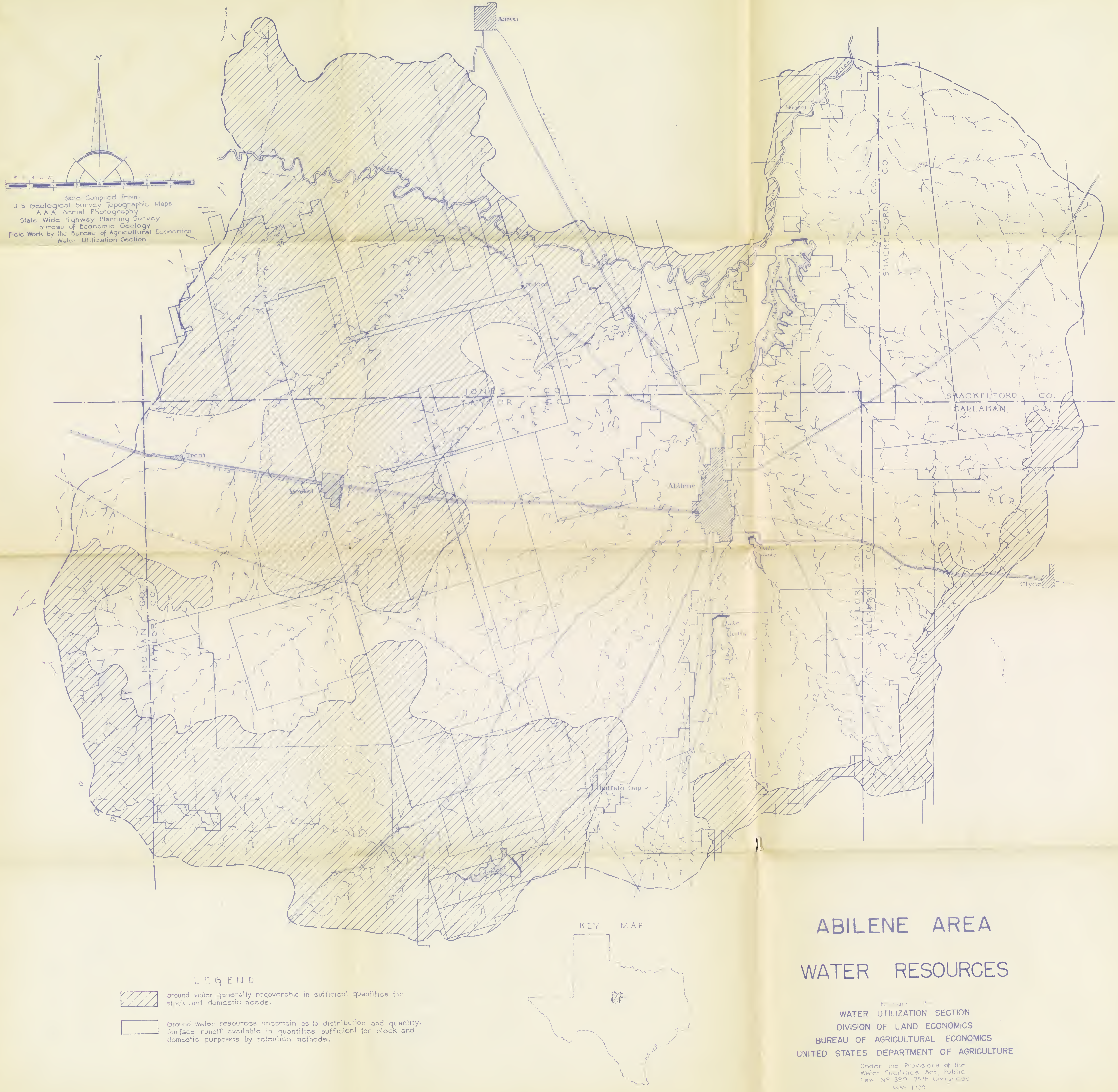
MAPS

Aug 1939 #1



LEGEND

Ground water generally recoverable in sufficient quantities for stock and domestic needs.

Ground water resources uncertain as to distribution and quantity. Surface runoff available in quantities sufficient for stock and domestic purposes by retention methods.

ABILENE AREA

WATER RESOURCES

Prepared by

WATER UTILIZATION SECTION
DIVISION OF LAND ECONOMICS
BUREAU OF AGRICULTURAL ECONOMICS
UNITED STATES DEPARTMENT OF AGRICULTURE

Under the Provisions of the Water Facilities Act, Public Law Nº 399 75th Congress
MAY 1939

PLATE NO. 1

Age	Series	Formation	Lithologic Character	Symbol
Cretaceous	Fredricksburg (Undifferentiated)	Edwards	Massive, cherty limestone	
		Comanche Peak	Chalky sand-limestone.	Kf
		Walnut	Sandy clay and marl.	
	Trinity	Paluxy	Soft sands and sandstones-red & white clays	Kt
Carboniferous (Permian)	Double Mountain	Dog Creek Blaine	Shales and gypsum	Cdb
		San Angelo	Sandstone and shales.	Csa
	Clear Fork (Undifferentiated)	Choza	Red shales and clays.	
		Vale	Sandy shales, sandstones, dolomites	Ccf
		Arroyo	Black shales-dolomites	
	Wichita	Leuders	Limestones and shales.	Cw

ABILENE AREA
GEOLOGY

[illegible]
WATER UTILIZATION SECTION
DIVISION OF LAND ECONOMICS
BUREAU OF AGRICULTURAL ECONOMICS
UNITED STATES DEPARTMENT OF AGRICULTURE

Under the Provisions of the Water Facilities Act, Public Law Nº 399 75th. Congress
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PLATE NO. 2